NMSP – Food Security - AQUATIC ANIMAL HEALTH AND BIOSECURITY

a. Abstract

With the expansion of the aquaculture sector in Australia over the past three decades, there has been a need to develop capability, capacity and expertise in aquatic animal health and biosecurity. This paper discusses the current status of Australia's capability and capacity to address industry and regulatory needs, knowledge gaps requiring further research and priority areas of research into the future. Options for developing resources for the efficient and effective implementation of these priorities including delivery to the end-users are considered.

b. Background

Aquatic animal health and biosecurity is a field of research activity that had little attention in Australia until 1981 with the establishment of a national fish health reference laboratory. Coincidentally, Australian aquaculture was at the start of a rapid growth period which continues to the present day. Currently, aquaculture is the fastest growing primary industry in Australia where it provides regional employment and makes a significant contribution to Australia's export earnings. For example, the Southern Bluefin Tuna industry in Port Lincoln is valued at AU$150 million (ABARES, 2013), and employs 1500 people (Derkley, 2014).

With the growth in Australian aquaculture over the past three decades there has been an increased need for research to address knowledge gaps brought about the increase in the diversity of aquatic species under culture and the establishment of aquaculture enterprises in new environments throughout Australia. As a direct result of these developments there has been a parallel increase in the need for research capacity and capability in aquatic animal health. Research on aquatic animal health and biosecurity is currently undertaken by Commonwealth and State Government departments, some universities including veterinary medicine faculties (see Table 1).

Table 1. Summary of Key Organisations with Research Capability/Capacity in Aquatic Animal Health and Biosecurity

Government	Universities
CSIRO	University of Tasmania
DPIPWE, Tasmania	Flinders University
DEPI, Victoria	University of Queensland
DPI, NSW	Charles Sturt University
SARDI	Macquarie University
Fisheries WA	University of Melbourne
DPIF, NT	University of Sydney
QDAFF	University of Adelaide
	Murdoch University
	James Cook University

The 2013 national capacity audit found that 31 scientist work in aquatic animal health. There was no separate data for scientists working on food related biosecurity (http://frdc.com.au/research/final-reports/Pages/2013-410-DLD.aspx).

Although the need for research has increased over this period, the number of research providers has not changed significantly. Consequently, the range of research undertaken by the current core of research providers has, of necessity, expanded. Furthermore, with this long-term commitment, many research providers have developed a national and international reputation in aquatic animal health such that several of them lead international OIE Reference Laboratories for globally significant diseases/pathogens of aquatic animals, e.g. yellowhead disease of prawns, abalone herpesvirus, epizootic haematopoietic necrosis and ranavirus (OIE, 2014).

In 1995, and again in 1998, a mass mortality event involving a herpesvirus infection of Australian sardines extending the full geographical range of this species precipitated a review of aquatic animal health in

Australia (Hyatt *et al*., 1997). One of the consequences of this review, which concluded in 1999, was the establishment of the FRDC Aquatic Animal Health Subprogram (AAHS) in 2000 which managed a substantial portfolio of research, funded through an agreement between the Commonwealth Government and FRDC, aimed at addressing knowledge gaps in aquatic animal diseases, including their diagnosis and management, as well as training and people development. Following its establishment, AAHS has remained as one of FRDC's Sub-programs and manages the aquatic animal health and biosecurity portfolio of projects within this funding organisation.

Other sources of funding include Commonwealth Government departments such as Department of Agriculture and Biosecurity Australia, CSIRO and State Government departments, universities and veterinary medicine faculties as well as direct funding from industry sectors. Current funding levels are insufficient to address the growing list of endemic and emerging diseases that hold back industry development.

c Relevance

With the growth in Australian aquaculture over the past three decades there are many research issues to be addressed, including research of aquatic animal diseases and health. In comparison with the terrestrial animal industries, the state of knowledge of aquatic animal health management is limited. Research has a critical role in expanding this knowledge and enhancing management practices to prevent disease or limit its impact on the expanding fisheries/aquaculture sector, including recreational fisheries and natural resources.

The beneficiaries of this research are the fisheries and aquaculture sectors including the ornamental and recreational fisheries and the managers of the aquatic natural resources, i.e. State government departments of fisheries/environment/natural resources and/or primary industries and/or agriculture. In addition, Commonwealth Government departments (Agriculture and Biosecurity) have research needs to address national issues relating to aquatic animal health and biosecurity such as quarantine-related issues and issues related to Australia's disease status.

To ensure that end-users are engaged in setting research priorities there are a number of processes available to governments, industry and research providers. The Australian Government Animal Health Committee (comprised of the Commonwealth and State Chief Veterinary Officers, the Director of CSIRO-AAHL, Biosecurity Australia representative and a New Zealand representative) established a sub-committee (Sub-committee for Aquatic Animal Health – SCAAH) to provide advice on policy and technical matters of aquatic animal health concern. SCAAH is comprised of aquatic animal health specialists from each State/Territory Government, Australian Government Department of Agriculture, CSIRO-AAHL, as well as a university representative and an industry observer (from National Aquaculture Council representing fisheries and aquaculture industries). SCAAH is also linked to other Australian Government committees/subcommittees such as the Aquaculture Committee and the Sub-committee on Animal Health Laboratory Standards (SCAHLS). SCAAH meets quarterly and in addition to policy and technical matters also discusses research needs. See the Aquavetplan - http://www.agriculture.gov.au/animal-plant-health/aquatic/aquavetplan.

In addition to SCAAH, the national Research Providers Network (RPN) established an Aquatic Animal Health and Biosecurity Hub which is comprised of representatives from the major research providers for aquatic animal health and biosecurity from each jurisdiction. As part of its mandate, this committee ensures that, as far as possible, jurisdictions exchange information on their research priorities to identify potential areas of common interest, and therefore opportunities for collaboration, as well as ensuring there is no duplication of effort, nationally.

As a provider of funds for aquatic animal health research in Australia, FRDC's AAHS provides a cohesive and national approach to aquatic animal health research and development in Australia. AAHS ensures that projects address end-users' priorities, understanding that the end-users include the Australian fisheries sector (wild-catch, aquaculture and recreational fisheries, and natural resources) and government policy makers and regulators.

The FRDC AAHS Leader is also a member of SCAAH, SCAHLS, the RPN Aquatic Animal Health and Biosecurity Hub. This combined with a number of other research providers in the field of aquatic animal health who are also members of these committees ensures that there is good communication between these various committees/fora.

d. Science needs

Australia's fisheries/aquaculture continues to be a major sector of our primary industries in terms of both job creation and value of production. The sector’s capacity to contribute through export earnings and job creation especially in regional Australia is a vital part of our future prosperity. In 2011/12 Australian fisheries production was valued at AU$2.35 billion (AU$1.30 billion for the wild-catch sector and AU$1.05 billion for aquaculture), with the value of aquaculture continuing to grow on an annual basis. Australia is a net importer of fisheries products (both edible and non-edible) consisting of exports valued at AU$1.23 billion while imports total AU$1.61 billion (ABARES, 2013).

Australia is fortunate to have an aquatic animal sector free from many diseases that cause significant economic impact elsewhere in the world (see McColl *et al*., 2004 for example). It is vital for Australia to maintain this high-health status, not only to enhance our competitiveness but also to protect Australia’s natural resources. However, Australia also has a unique range of poorly understood host species and endemic pathogens including local strain variations of pathogens of international concern (e.g. Davies *et al*., 2010), which are becoming increasingly important and of significance to our export trade. Examples of significant pathogens/diseases currently in Australia include Ostreid herpesvirus (a pathogen of edible oysters in Australia and overseas), Oyster Oedema Disease (a disease of pearl oysters in Australia), Abalone herpesvirus (a pathogen of abalone in Australia and overseas; Corbeil *et al*., 2010), salmon orthomyxo-like virus (a pathogen of farmed Atlantic salmon in Tasmania)), *Cardicola* spp. in Southern Bluefin tuna (Dennis *et al*., 2011; Polinski *et al*., 2013) and yellow head-related viruses (a complex of viral pathogens of prawns in Australia and overseas; Wijegoonawardane *et al*., 2008).

Compared to the terrestrial animal industries, the state of knowledge of aquatic animal health management including the epidemiology of disease threats, physiology of the hosts and technology for managing disease is limited. Research has a critical role in expanding this knowledge and enhancing management practices to prevent disease or limit its impact on the expanding fisheries/aquaculture sector, including recreational fisheries and natural resources.

Globally, both domesticated (farmed) and wild aquatic animal populations are affected by emerging diseases and there is increasing evidence that Australia is not exempt. The impacts of emerging diseases can be wide-ranging including direct economic losses not only in the affected aquaculture enterprise but also in associated industries. Other impacts include a reduction in ecosystem stability and sustainability (e.g. impacts of reduced pilchard populations on the food chain), loss of cultural heritage (extinction of native species) and reduced regional employment.

The outcomes of efforts to manage diseases in farmed aquatic animals have been limited (c.f. recent Ostreid herpesvirus outbreaks, see http://www.dpi.nsw.gov.au/fisheries/pests-diseases/animal-health/aquaculture/poms; amoebic gill disease in Atlantic salmon; Munday *et al*., 2001), and controls to manage disease outbreaks in wild populations, if any, are limited (c.f. 1995/98 pilchard mortalities, Whittington *et al*., 2008; 2006 abalone herpesvirus incident, Mayfield *et al*., 2011). While eradication of disease in the aquatic environment is difficult, it is possible (Stagg, 2002; Stone *et al*., 2008; Dale *et al*., 2009; Jensen *et al*., 2014) with concerted, persistent and resource-intensive effort. The direct and indirect economic impact of disease can mount into the billions of dollars (Lightner, 2003; Bondad-Reantaso *et al*., 2005; Walker & Mohan, 2009) without attempting to quantify environmental impacts. For many diseases it is conceivable that they will continue to spread not only because pathogens in the aquatic environment are difficult to control but also because there is limited understanding of their biology. There is, for example, inadequate understanding of the factors that trigger disease emergence; poor understanding of immunity and/or disease resistance mechanisms in aquatic animal species, particularly invertebrates (molluscs and crustaceans) with few examples of effective vaccines for viral diseases of aquatic animals; there is limited information on geographical and host ranges; there is a poor understanding of the pathogen/host/environment interaction and the mechanisms of disease transmission within populations and other critical epidemiological factors such as biological reservoirs and vectors, stability in the environment and ways to manage disease. In addition, there is limited availability of fully validated diagnostic tests particularly for the detection of sub-clinical infections.

With expanding aquaculture, the range of native aquatic animals being farmed is also increasing which, in turn, increases the need for research on aquatic animal health issues. Thus in Australia there are about 70 aquatic species under aquaculture development of which 40 are farmed commercially. Australia is therefore in an excellent position to take advantage of the global increase in demand for quality seafood. It is inevitable, however, that new diseases will emerge and, currently, we are unable to predict where and when the next threat will arise. Research on all types of aquatic animals (finfish, crustaceans, molluscs and amphibians) from all environments, i.e. tropical or temperate, marine, brackish or freshwater environments, is required. By supporting research on the diseases of current concern, Australia will build capability, capacity and expertise in all areas of aquatic animal health which will contribute to ensuring that the fisheries and aquaculture sectors build resilience and continue to grow in a sustainable manner providing Australia with the concomitant socio-economic and environmental benefits into the future.

e. Perspective

The increased, and growing, movement of people and commodities on a global scale is a major risk factor contributing to the spread of disease (Hine *et al*., 2012). Increased trade causes a concomitant increased in risk. The risk of introduction of exotic disease, via various pathways, is a major concern and a constant threat to the aquatic environment and natural resources, and to wild and farmed fisheries. It is a priority for Australia to ensure that knowledge of known exotic diseases remains current and that systems are in place for the rapid detection of any exotic incursion and for the efficient management and control of any exotic disease outbreak. Collaboration with international experts is of mutual benefit to better understand the host and geographical ranges of pathogens, the range in genetic variability within each pathogen, mechanisms by which the spread of diseases occurs internationally and the mechanisms by which local variants of infectious agents emerge. Moreover, sharing of knowledge will assist the improvement of husbandry measures and identification of selective breeding strategies (development of disease-resistant families) aimed at the prevention of disease outbreaks.

Australia has some unique aquatic fauna and so has a range of unique pathogens that are poorly understood (e.g. oyster oedema disease). In addition to the threat of exotic disease, as new species are introduced to new habitats such as those involving intensive aquaculture conditions, new diseases will emerge with the potential to spill over to wild populations. As part of the development of new aquaculture species, in addition to research in artificial breeding, genetics, nutrition, husbandry, hatchery production, grow-out etc., research into the pathogen that are potential disease threats and the physiology and immunology of the host species should be incorporated into the research portfolio.

It is likely that climate change will be an additional factor influencing the emergence of diseases in aquatic animals (Rodger & McArdle, 1996; Leung & Bates, 2013). Apart from impacting on the suitability of potential sites for aquaculture and mariculture, climate change will alter the pathogen/host/environment interaction by influencing the replication rate of infectious agents, the host immune response to infection, and environmental stressors such as changes in temperature, all of which may increase susceptibility to disease. In addition to a direct impact on the pathogen and host species, there is potential for changes in the geographical range of susceptible wild species and of reservoirs and vectors of infectious agents (Pullin & White, 2011).

f. Realisation

Due to its size, Australia presents formidable challenges with respect to efficient use of resources. This is particularly true for fisheries and aquaculture research, understanding that the species of interest are distributed across a range of environments (freshwater, brackish and marine) encompassing tropical to temperate climates. Research providers at the state level have developed interest and capability relevant to the local fisheries and aquaculture sectors; in Tasmania there is capability in salmonids, rocklobster and molluscs; in Victoria rainbow trout, eels, rocklobster and molluscs; in South Australia tuna, yellowtail kingfish, rocklobster, prawns and molluscs; in Western Australia pearl oysters, rocklobster and prawns; in NT pearls, goldband snapper, mud crab, barramundi and mackerel; in Queensland prawns, coral trout, crabs and barramundi; NSW oysters, prawns, sea mullet and rocklobster; and for Commonwealth waters prawns, tuna and sharks.

Australia is a large continent with a wide range of biogeographic zones. This has led to a diversified aquaculture and fisheries sector. Each component appears to be subject to a unique suite of problems, with some common diseases. There has been national support for establishment of a decentralised aquatic animal health network comprising government laboratories and research departments in universities to address this diversity. This model, with disseminated expertise around Australia appears to be essential for future growth of the industry, but resources are very limited. For research on enzootic pathogens, laboratories and experimental aquarium facilities, accredited to physical containment level 2 (PC2), are required. To address the broad range of aquatic species of interest, a recommended approach is to develop nodes of expertise or centres of excellence that build on current capability and capacity.

Table 2. Developing Aquatic Animal Health Centre of Excellence in Australia

Aquatic Animal species/groups - examples	Aquatic Animal Health Research Providers
Salmonids; temperate molluscs	University of Tasmania; DPIPWE Tasmania; CSIRO-AAHL; University of Adelaide
Tuna; rocklobster	SARDI; University of Adelaide; Flinders University
Prawns	CSIRO Brisbane; DAFF Queensland; James Cook University, Qld; CSIRO-AAHL
Edible oysters, finfish, ornamental fish	NSW DPI; University of Sydney; University of Adelaide; CSIRO-AAHL
Abalone	DEPI Victoria; CSIRO-AAHL, SARDI
Pearl oysters	Fisheries WA; DPIF NT; Macquarie University
Barramundi and tropical finfish; mud crabs	DPIF NT; DAFF Queensland; University of Queensland; CSIRO-AAHL; University of Adelaide
Yellowtail kingfish	SARDI; University of Adelaide; University of Tasmania

Not only do centres of excellence need to develop and maintain expertise on the biology of specific aquatic animal species of socio-economic significance, including their diseases but also there needs to be development of expertise within disciplines such as epidemiology, virology, bacteriology, parasitology, mycology, immunology, pathology, diagnostics, exotic diseases that will provide comprehensive capability and capacity for aquatic animal health.

To provide a comprehensive research capability for exotic diseases/pathogens, laboratories and experimental facilities accredited to the higher physical containment level, PC3, are required. The CSIRO Australian Animal Health Laboratory (AAHL) in Geelong is the only facility in Australia authorised to undertake experimental infections (in animals) with exotic disease agents. AAHL was commissioned in the 1980s and was designed to undertake research on exotic diseases of traditional livestock which back then did not include aquatic animals. The Australian Fish Health Reference Laboratory (AFHRL) relocated from the Benalla Regional Veterinary Laboratory to AAHL in 1989, in part to allow research on exotic viruses. Subsequently, the focus of the AAHL Fish Diseases Laboratory was, and continues to be, on exotic, new, and emerging diseases of aquatic animals (currently finfish, molluscs and crustaceans). Some basic experimental aquarium facilities were established in the AAHL PC3 facility. While these facilities are useful for undertaking short-term acute pathogenicity trials, they are inadequate for longer term experiments, for example, those aimed at investigating immune responses of aquatic animals and longer term vaccination trials using exotic agents, and other projects requiring PC3 facilities. In the past, funding proposals for the development of a state-of-the-art PC3 aquarium facility for research on exotic diseases of aquatic animals at AAHL has not been approved. Such a facility would be available for research projects addressing national priorities. The PC3 level of containment would also permit its use for research on exotic agents of international significance and thus promote collaboration with international centres of excellence in Europe, the Americas and Asia.

g. Additional comments

An important need is to establish greater links between oceanography and limnology, estuarine and coastal ecosystem management science and aquatic animal health research because environmental change is a potential driver for emerging disease. Hydrodynamic events are often central to spread of disease in aquatic environments, but are poorly studied and are not well understood. Centres of excellence that bring people together from across disciplines are urgently needed to tackle current and emerging diseases.

Diseases in aquatic animals are less well understood than diseases in terrestrial animals. Despite much research effort over 30 years in Australia (and longer overseas) solutions to many significant aquatic animal health problems remain elusive.

Management of diseases in Australian aquaculture is further hampered by the paucity of aquatic chemicals and veterinary products registered for use in Australia. Registration of these products in Australia is unattractive to suppliers of the products because of the high cost of registration (generating *de novo* local data on efficacy, pharmacokinetics in treated animals, and environmental fate of the product used is required for registration), relative to the modest quantities of product required to satisfy the Australian market. This market failure needs to be addressed by targeted research on efficacy, pharmacokinetics, residues and environmental effects, and further vaccine development. Importantly, controlled science-based field studies to assess pharmaceutical, vaccine and husbandry interventions to control disease must also be expanded. This requires teams with multidisciplinary research capability.

There are substantial gaps in current aquatic disease policy, knowledge, application of management, and access to funding for a range of diseases of environmental importance but which are not linked to fisheries or aquaculture industries, including diseases of aquatic plants, marine mammals, amphibians and other organisms of ecological value.

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Attachments

History of aquatic animal diseases/infectious agents in Australia: A summary

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YEAR	PATHOGEN/DISEASE
2013	Yellowhead virus/Gill-associated virus genotype 7 in prawns (Qld)
2012	*Megalocytivirus* in ornamental fish farm (Qld)
	Orthomyxo-like virus in salmonids (SE Tas)
2011	Viral ganglioneuritis in farmed abalone (Tas)
2010	*Edwardsiella ictaluri* in native catfish (NT)
	Barramundi herpesvirus (Vic)
	Ostreid herpesvirus in Pacific oysters (NSW)
	Aquabirnavirus in trout (Vic)
2008	Blood fluke (*Cardicola fosteri*) in southern bluefin tuna (SA)
	Mortalities (*Streptococcus* sp.) in (wild) grouper (Qld)
	Kingfish mortalities (WA)
	Abalone viral ganglioneuritis in processing plants (Tas)
	White tail disease - *Macrobrachium rosenbergii* nodavirus (Qld)
	New strain (previously exotic) of IHHNV in prawns (Qld)
2007	Orthomyxo-like virus in salmonids (Tamar River, Tas)
2006	Eel mortalities – rhabdovirus? (Vic)
	Oedema disease in pearl oysters (WA)
	Viral ganglioneuritis in wild abalone (Vic)
2005	Carp mass mortality (Vic)
	Viral ganglioneuritis (AVG) in farmed abalone (Vic)
	GAV in *Fenneropenaeus merguiensis* (WA)
2004	Nodavirus in Australian bass & other finfish (NSW)
	Leatherjacket mass mortality (NSW)
2003	Iridovirus in Murray cod (Vic)
	Infectious hypodermal and haematopoietic necrosis virus (integrated sequence?) confirmed in *P. monodon* (Qld)
	Herpesviral haematopoietic necrosis in goldfish (WA)
2001	Rickettsia-like organism (RLO) in salmonids (Tas)
	Ciliate infection/disease in pearl oysters (WA)
2000	Barramundi hump-back syndrome
	Parvo-like virus in redclaw crayfish (Qld)
1998/9	Pilchard herpesvirus (all southern states)
	Orthomyxo-like virus (pilchards, SA)
	Aquabirnavirus (salmonids, Tas)
	Thelohania (yabbies, WA)
1997	*Uronema nigricans* (tuna, SA)
	Hepatopancreatic parvo-like virus in *P. japonicas* (Qld)
	Ciliate infection/disease in pearl oysters (WA)
1996	Gill-associated virus (*Penaeus monodon*, Qld)
	Mourilyan virus in *P. Monodon* (Qld)
	Bennettae baculovirus in *Metapenaeus bennettae* (Qld)
1995	Pilchard mass mortalities - Pilchard herpesvirus (all southern states)
	Haplosporidiosis (pearl oysters, WA)
1994	Atypical *Aeromonas salmonicida* (salmonids, Tas)
	Mid-crop mortality syndrome (prawns; Qld)
1993	RLO in giant clam, *Tridacna gigas*
	Redfin perch Aquareovirus (Vic)
	Penaeid haemocytic rod-shaped virus in hybrid penaeid prawn
	Monodon baculovirus in *P. Monodon* (Qld)
	Papova-like virus infection (pearl oyster, WA)
1992	Lymphocystis (snapper, SA)
	IHHNV in hybrid penaeid prawn (Qld)
	Bonamia sp. (edible oysters, Vic)
1991	Lymphoidal parvovirus in *Penaeus monodon*, *P. merguiensis*, *P. esculentus* (Qld)
1990	Lymphocystis (barramundi)
	Parvo-like virus in *Macrobrachium rosenbergii* (Qld)
1989	Nodavirus (barramundi, Qld)
	Atlantic salmon aquareovirus (Tas)
	Hepatopancreatic parvovirus in *Penaeus merguiensis* (Qld)
1988	Mycobacteriosis (trout, Vic)
1987	Penaeus baculovirus in *Penaeus plebejus* (Qld)
1986	Amoebic gill disease (Atlantic salmon, Tas)
1984	Epizootic haematopoietic necrosis virus (redfin & rainbow trout, Vic)
1980s	*Perkinsus* sp. (NSW)
	Marteilia sydneyi (NSW)
	Vibriosis (pearl oysters, WA)
	Flexibacter, *Yersinia ruckeri*, *Vibrio* (salmonids, Tas);
1980	Goldfish ulcer disease (Atypical *Aeromonas salmonicida*, Vic)
1970	Epizootic ulcerative syndrome (fungal infection of finfish, NSW, NT, Qld, Vic, SA and WA)